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Trace Elements in Canadian Coals

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Air Pollution Control Directorate
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TRACE ELEMENTS IN CANADIAN COALS

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Air Pollution Control Directorate

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ABSTRACT

In this report, the concentrations of 42 trace elements in coal are given for 38 samples of coal obtained from coal fields across Canada. Neutron activation analysis was the principal analytical method used in the study; however, plasma emission spectrometry and flame atomic absorption spectrometry were also used. For some of the trace elements, the accuracy of the three analytical methods was checked by using two standard reference coals supplied by the United States National Bureau of Standards.

RÉSUMÉ

Le présent rapport donne les concentrations de 42 éléments à l'état de trace qui sont présents dans 38 échantillons de charbon provenant de gisements de tout le Canada. La méthode principale utilisée de dosage a été l'activation neutronique, mais on s'est aussi servi de la spectrométrie d'émission de plasma et de la spectrométrie d'absorption atomique de flamme. Pour certains des éléments, l'exactitude des trois méthodes a été vérifiée à l'aide de deux étalons de charbon fournis par l'United States National Bureau of Standards.

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1 INTRODUCTION

Canada's coal reserves are estimated to be about 120 billion tons, of which about six billion tons are considered to be economically recoverable. With such large reserves, particularly when compared to the much more limited reserves of indigenous oil and natural gas, it is anticipated that coal will play an increasingly important role in Canada's future energy supply. Currently, Canadian coal production is about 30 million tons per year, and this is expected to increase to about 100 million tons annually by the year 2 000.

However, in spite of its large reserves, coal is recognized environmentally as a "dirty" fuel, and the development of efficient, cost-effective control measures for sulphur dioxide, nitrogen oxides, and particulate emissions from coal combustion have, in recent years, been the focus of major national and international efforts and concerns. In addition, it is anticipated that future concerns related to coal usage could well be directed to the emission to the environment of trace elements present in coal during various stages of the coal extraction/utilization cycle, i.e., mining, preparation, transportation and conversion or combustion. Currently, any attempt to assess the significance of these emissions is severely limited by a lack of information on the concentration of trace elements in Canadian coals and, as a consequence, this study was undertaken as a first, systematic effort to provide such information for representative coal deposits across Canada. In doing so, it is recognized that coal is inherently an inhomogeneous substance and that much additional work will be required to characterize more fully the trace element concentrations; nevertheless, it is hoped that the present initial survey will provide useful insight and guidance to those involved in this area.

2 COAL SAMPLES AND ANALYTICAL PROCEDURES

The coal samples used in this study were provided by the Fuels Research Laboratories, Department of Energy, Mines and Resources, Ottawa, and had been collected and prepared according to standard methods. The samples are representative of coal deposits across Canada, and range in rank from lignite to high-volatile bituminous coal. Proximate and ultimate analyses of the coals are given in Table 1, together with the mercury content of some of the coals (1).

For this investigation, each coal sample (which was received pre-ground to about 100-mesh) was divided into three parts; one part was used "as received" for analysis

by non-destructive or instrumental neutron activation analysis (NAA); the second part was dissolved (see Appendix 1 for destructive dissolution methods) and portions of the solution were used for analysis by plasma emission spectrometry (PES) and by flame atomic absorption spectrometry (AAS); the third part was retained for future analyses and reference purposes.

The NAA determinations were performed by Commercial Products, Atomic Energy of Canada Ltd., Ottawa, using an AECL Slowpoke 2 reactor as a neutron source (thermal neutron flux, $5 \times 10^{11} n/cm^2\text{-}s$). With the exception of uranium, which was determined by delayed neutron counting, the concentrations of all the trace elements were measured by gamma-ray spectrometry using solutions containing the elements being determined as reference standards. The errors quoted for the NAA measurements are the sum of a 5% error resulting from neutron flux and counting geometry variations, weighing errors, etc., plus a one-standard-deviation counting-error due to the statistics of radioactive decay.

The PES determinations were made by Barringer Magenta Research Ltd., Rexdale, Ontario, using an analytical procedure similar to that developed by the United States Environmental Protection Agency (2).

The AAS measurements were made by the Laboratory Services Division, Air Pollution Control Directorate, Environment Canada, who were also responsible for preparing the solutions for the PES measurements.

A summary of the elements determined by each of the analytical methods is given in Table 2.

To check on the validity and applicability of these analytical techniques for the determination of trace elements in coal, two standard reference coals (NBS 1632 and 1632a) from the National Bureau of Standards (NBS) were used as comparators for 22 of the trace elements determined in this study. A detailed comparison of the analytical data is given in Appendix 2, and it may be concluded that the three analytical techniques gave results that were in acceptable agreement with the NBS certified trace element concentrations.

3 RESULTS

The concentrations of trace elements in the 38 coal samples analyzed in this study are given in Tables 3, 4 and 5, for measurements made by NAA, PES and AAS, respectively. It will be noted from these tables that not all of the 42 elements reported

were measured independently by each of the three analytical methods; this was due primarily to the characteristics of the methods used. Thus, 25 of the elements were determined by only one method (NAA or PES), 15 elements were determined by two methods, and two elements were determined by all three methods. For those elements determined independently by two techniques (NAA and PES, or PES and AAS), an element-by-element comparison of the analytical results is given in Tables 6 and 7; in general, satisfactory agreement was found between the methods.

The trace element concentration data given in Tables 3-5 indicate that the concentration of a given element can vary widely from sample to sample and that only general observations can be made concerning the concentration of a particular element in different coals across Canada. This situation is exemplified by the following comments on some of the elements determined in the present study.

Arsenic — For the 31 coals from Western Canada (Saskatchewan, Alberta and British Columbia), the arsenic concentration in all but two of the coals (at 11.6 and 13 ppm) was less than 10 ppm, and the majority of the coals had arsenic concentrations below 2 ppm. In contrast, all but one of the Eastern coals (at 4.3 ppm) had arsenic concentrations above 10 ppm, and the arsenic concentration in the two New Brunswick coals was 131 and 311 ppm.

Beryllium — The concentration of beryllium showed no significant variation among the coals and had an average value of about 0.9 ppm.

Boron — Among the Western coals, those from Saskatchewan, on average, had the highest boron concentration (about 1250 ppm) and those from Alberta the lowest (about 860 ppm). Results were obtained for only two Nova Scotia coals at 119 and 1872 ppm.

Cadmium — Relatively few measurements were obtained for cadmium and the values showed no dependence on the coal source; they ranged from 6.6 to 8.8 ppm.

Lead — With the exception of three samples from Nova Scotia (at 52.6, 52.7 and 55.4 ppm), all the samples contained less than 20 ppm lead, with most containing between 2 and 10 ppm. In general the coals from British Columbia and New Brunswick had the lowest lead concentrations.

Selenium — The two coals from New Brunswick contained 4.9 and 10.9 ppm. All the other coals contained less than 4 ppm selenium.

Thorium The thorium content showed no marked dependence on coal source and nearly all the samples contained between 1 to 3.5 ppm. Two Nova Scotia coals (0.2 and 0.3 ppm) and two Alberta coals (4.8 and 6.17 ppm) were outside this range.

Uranium The uranium content of the coals was generally less than 2 ppm. However, one coal from Nova Scotia contained 2.2 ppm and four coals from Saskatchewan ranged from 2.12 to 2.91 ppm.

Vanadium The vanadium content was generally lowest for Saskatchewan coals (5 to 17.5 ppm) and highest for British Columbia coals (18.6 to 108 ppm). The Eastern coals had an average vanadium concentration of about 25 ppm.

4 CONCLUSIONS AND RECOMMENDATIONS

The concentrations of 42 trace elements in coal have been determined for 38 samples of coal taken primarily from commercial coal operations across Canada. Since only one sample from each source was analyzed, it is recommended that similar analyses should be undertaken for other samples from the same deposits in order to confirm the validity of the present results and also the regional concentration differences shown by a number of the trace elements. In the meantime, those involved in the pollution assessment and control fields will be able to use the data given in this report to estimate the potential environmental impacts resulting from the presence of various trace elements in Canadian coals during all phases of the coal extraction/utilization cycle.

REFERENCES

1. Private communication with W.J. Montgomery, Department of Energy, Mines and Resources, Ottawa.

TABLE I PROXIMATE AND ULTIMATE ANALYSES AND MERCURY CONTENT OF COALS

Company	Field	Mine	Proximate Analysis (Air dried) Moisture wt %	Ash wt %	Volatile Matter wt %	Fixed Carbon wt %	Ultimate Analysis (Air dried) Carbon wt %	Hydrogen wt %	Sulphur wt %	Nitrogen wt %	Ash wt %	Oxygen wt %	Calorific Value MJ/kg	Mercury ppm
NOVA SCOTIA														
River Herbert	Joggins	River Herbert	1.71	32.37	27.34	38.58	53.58	3.56	4.10	1.20	32.37	3.48	21.67	0.29
Thorburn	Pictou	Acadia	1.29	28.23	22.91	47.57	-	-	(0.97)	-	(28.23)	-	23.47	-
Devco	Sydney	Lingan	1.02	3.16	34.35	61.47	-	-	(1.04)	-	(3.16)	-	-	-
Devco	Sydney	No. 26	0.94	2.18	33.70	63.18	-	-	(0.79)	-	(2.18)	-	-	-
Devco	Sydney	Prince	1.79	18.80	30.79	48.62	62.42	4.34	5.03	1.28	18.80	6.34	-	-
NEW BRUNSWICK														
N.B. Electric Power	Minto	Minto	1.38	18.15	32.32	48.15	65.39	4.37	7.10	0.97	18.15	2.64	28.24	0.60
N.B. Coal	Minto	Minto	0.67	23.77	-	-	58.02	3.73	10.66	0.74	23.77	2.41	-	1.23
SASKATCHEWAN														
Manitoba Power	Estevan	Estevan	20.95	11.31	32.17	35.57	48.69	3.10	0.47	0.81	11.31	14.67	18.66	0.07
M&S Coal	Estevan	Bienfait	26.18	11.64	29.00	33.18	-	-	(0.36)	-	(11.64)	-	17.87	-
M&S Coal	Estevan	Boundary Dam	21.28	13.61	29.55	35.56	46.82	3.04	0.29	0.95	13.61	14.01	17.91	0.07
Sask. Power Corp.	Estevan	Boundary Dam	19.52	13.46	31.34	35.68	48.32	3.18	0.50	0.92	13.46	14.10	18.83	0.06
Sask. Power Corp.	Estevan	Queen Eliz.	19.88	10.03	31.18	38.91	51.96	2.98	0.41	1.13	10.03	13.61	19.83	0.06
Manalta	Estevan	Klimax	11.96	13.57	32.98	41.49	54.24	3.37	0.64	0.96	13.57	15.26	20.92	0.11
Poplar River	Core Sample	Exploratory	21.68	18.19	29.27	30.86	42.21	2.81	0.65	0.60	18.19	13.86	15.86	-
Poplar River	Core Sample	Exploratory	12.91	17.30	33.23	36.56	49.11	3.21	0.60	0.66	17.30	16.21	18.45	-

Data given in parentheses under Ultimate Analysis are the only values available for these coals.

TABLE 1 PROXIMATE AND ULTIMATE ANALYSES AND MERCURY CONTENT OF COALS (cont'd.)

Company	Field	Mine	Proximate Analysis (Air dried) Moisture wt %	Ash wt %	Volatile Matter wt %	Fixed Carbon wt %	Ultimate Analysis (Air dried) Carbon wt %	Hydrogen wt %	Sulphur wt %	Nitrogen wt %	Ash wt %	Oxygen wt %	Calorific Value MJ/kg	Mercury ppm
ALBERTA														
Manalta	Sheerness	Roselyn	23.73	11.20	31.74	33.33	-	-	(0.41)	-	(11.20)	-	18.58	-
McIntyre	Grande Cache	McIntyre	0.37	7.27	19.21	73.15	83.37	4.31	0.41	1.09	7.27	3.18	33.43	0.13
McIntyre	Grande Cache	McIntyre	0.65	7.42	20.14	71.79	82.76	4.38	0.44	1.08	7.42	3.27	33.43	0.10
Luscar Coal	Castor	Diplomat	22.35	7.34	30.72	39.59	52.06	3.34	0.41	1.17	7.34	13.33	20.42	0.02
Manalta	Castor	Vesta	20.45	8.68	30.16	40.71	51.81	3.32	0.33	1.17	8.68	14.24	20.33	0.03
Century Coals	Drumheller	Atlas	16.73	9.06	30.29	43.92	55.09	3.40	0.46	1.25	9.06	14.01	21.50	0.04
Manalta	Pembina	Highvale	8.39	15.51	30.05	46.05	56.39	3.37	0.19	0.06	15.51	16.09	21.84	0.07
Manalta	Pembina	Whitewood	8.97	13.52	31.36	46.15	56.88	3.37	0.29	0.75	13.52	16.22	22.18	0.44
Sundance Mines	Edmonton	Sundance	13.61	13.84	29.12	43.43	54.89	2.19	0.21	0.67	13.84	14.60	21.00	-
Imperial Oil	Edmonton	Judy Creek	16.24	24.98	25.90	32.88	41.23	1.44	0.29	0.45	24.98	15.37	15.82	-
Coleman Collieries	Crowsnest	Vicary Creek	0.84	10.18	23.58	65.40	79.02	4.47	0.36	1.23	10.18	3.90	31.63	-
Coleman Collieries	Crowsnest	Tent Mountain	0.97	12.00	23.47	63.26	76.55	4.31	0.35	1.03	12.00	4.79	30.75	0.07
Cardinal River	Mountain Park	Cardinal River	0.95	9.16	26.17	63.72	79.68	4.63	0.26	1.09	9.16	4.23	32.13	0.10
BRITISH COLUMBIA														
B.C. Hydro	Ashcroft	Hat Creek	18.18	44.67	22.41	14.74	23.36	2.09	0.45	0.95	44.67	10.30	8.33	-
B.C. Hydro	Ashcroft	Hat Creek*	3.35	22.79	34.76	39.10	48.72	3.32	1.10	0.87	22.79	19.85	19.88	-
Tulameen	Tulameen	Tulameen	7.92	15.74	30.44	45.90	60.04	3.12	1.03	1.03	15.74	11.12	23.68	-
B.P. Canada	Chetwynd	Sukunka	1.07	15.63	22.15	61.15	75.05	4.20	0.59	1.14	15.63	2.32	30.33	-
Denison Coal	E. Kootenay	Denison	0.65	6.94	24.10	68.31	82.47	4.56	0.30	1.17	6.94	3.91	33.18	-
Byron Creek	E. Kootenay	Byron Creek	1.79	14.98	23.92	59.31	72.14	4.09	0.20	1.07	14.98	5.64	29.16	-
Kaiser Resources	E. Kootenay	Kaiser (Seam No. 7)	1.28	9.52	19.93	69.27	80.40	4.33	0.52	1.09	9.52	2.86	32.22	-
Kaiser Resources	E. Kootenay	Elk View	2.69	14.08	20.66	62.57	73.31	3.76	0.27	1.09	14.08	4.80	29.04	0.07
Kaiser Resources	E. Kootenay	Elk View*	1.26	9.92	20.14	68.68	80.27	4.44	0.34	1.17	9.92	2.60	32.64	0.06
Fording Coal	E. Kootenay	Fording	1.67	10.04	21.37	66.92	79.20	4.28	0.39	1.07	10.04	3.25	31.67	0.06

* Clean coal samples

TABLE 2 ELEMENTS DETERMINED BY EACH OF THE ANALYTICAL METHODS

Analytical Method	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Bromine	Cadmium	Calcium	Cerium	Chlorine	Chromium
NAA	X	X	X	X	-	-	X	-	-	X	X	X
PES	X	-	-	X	X	X	X	X	X	-	-	X
AAS	-	-	-	-	-	-	-	-	-	-	-	-

Analytical Method	Cobalt	Copper	Europium	Gadolinium	Hafnium	Iodine	Iron	Lanthanum	Lead	Magnesium	Manganese	Molybdenum
NAA	X	-	X	X	X	X	X	X	-	X	X	-
PES	X	X	-	-	-	-	X	-	X	X	X	X
AAS	-	X	-	-	-	-	X	-	X		X	

Analytical Method	Nickel	Phosphorus	Potassium	Samarium	Scandium	Selenium	Silver	Sodium	Strontium	Tantalum	Terbium
NAA	-	-	X	X	X	X	-	X	X	X	X
PES	X	X	X	-	-	-	X	X	X	-	-
AAS	-	-	-	-	-	-	-	-	-	-	-

Analytical Method	Thorium	Titanium	Uranium	Vanadium	Ytterbium	Zinc	Zirconium
NAA	X	X	X	X	X	-	-
PES	X	X	-	X	-	X	X
AAS	-	-	-	-	-	-	X

NAA - neutron activation analysis; used to analyze all coal samples
PES - plasma emission spectrometry; used to analyze all coal samples
AAS - atomic absorption spectrometry; used to analyze ten coal samples

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS

Company	Field	Mine	Aluminum ppm	% Err.	Antimony ppm	% Err.	Arsenic ppm	% Err.	Barium ppm	% Err.	Bromine ppm	% Err.	Cerium ppm	% Err.
NOVA SCOTIA														
River Herbert	Joggins	River Herbert	25 300	6	0.77	54	33.9	7	< 200	-	28.6	9	32.8	9
Thorburn	Pictou	Acadia	43 400	6	0.69	48	10.0	8	259	26	9.29	13	21.55	10
Devco	Sydney	Lingan	1 940	11	0.75	28	10.4	8	< 70	-	19.2	10	5.65	21
Devco	Sydney	No. 26	2 690	9	<0.3	-	4.33	10	< 60	-	7.61	12	2.61	36
Devco	Sydney	Prince	20 500	6	1.45	26	86.3	6	93.7	57	17.1	10	20.3	11
NEW BRUNSWICK														
N.B. Electric Power	Minto	Minto	10 100	6	<0.8	-	131	7	< 100	-	< 0.6	-	34.1	9
N.B. Coal	Minto	Minto	10 700	7	5.01	12	311	6	< 100	-	< 0.7	-	34.55	9
SASKATCHEWAN														
Manitoba Power	Estevan	Estevan	12 100	6	0.10	100	1.54	35	1 090	14	< 3.0	-	8.87	15
M&S Coal	Estevan	Bienfait	11 800	7	0.49	51	< 0.2	-	1 120	11	< 0.5	-	5.53	20
M&S Coal	Estevan	Boundary Dam	14 000	7	1.22	26	< 0.3	-	832	13	< 0.5	-	11.4	13
Sask. Power Corp.	Estevan	Boundary Dam	8 570	6	3.33	17	5.89	18	594	20	< 3.0	-	17.3	12
Sask. Power Corp.	Estevan	Queen Eliz.	10 500	6	<0.5	-	< 0.7	-	462	25	1.29	71	7.69	15
Manalta	Estevan	Klimax	14 000	6	<0.5	-	0.78	62	1 190	15	3.07	43	6.87	17
Poplar River	Core Sample	Exploratory	22 400	6	2.67	15	3.41	13	675	23	< 1.0	-	10.5	15
Poplar River	Core Sample	Exploratory	18 500	6	<0.5	-	4.82	14	413	33	1.87	40	11.2	14

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

Company	Field	Mine	Aluminum ppm	% Err.	Antimony ppm	% Err.	Arsenic ppm	% Err.	Barium ppm	% Err.	Bromine ppm	% Err.	Cerium ppm	% Err.
ALBERTA														
Manalta	Sheerness	Roselyn	13 200	7	<0.4	-	1.14	58	166	34	< 0.5	-	9.14	13
McIntyre	Grande Cache	McIntyre	10 800	7	0.42	59	6.07	12	301	20	10.8	14	8.18	17
McIntyre	Grande Cache	McIntyre	12 100	6	0.29	100	< 0.4	-	363	32	4.47	23	10.7	14
Luscar Coal	Castor	Diplomat	7 640	6	<0.3	-	< 1.0	-	308	29	< 2.0	-	4.29	24
Manalta	Castor	Vesta	10 100	6	<0.5	-	< 1.0	-	558	20	< 2.0	-	2.31	36
Century Coals	Drumheller	Atlas	12 800	6	0.93	24	< 0.9	-	395	29	1.70	68	11.1	12
Manalta	Pembina	Highvale	20 700	6	<1.0	-	1.09	36	617	23	< 2.0	-	14.8	11
Manalta	Pembina	Whitewood	15 300	6	<1.0	-	2.36	14	264	44	< 1.0	-	11.9	12
Sundance Mines	Edmonton	Sundance	14 700	6	0.29	76	0.62	67	570	23	10.7	17	18.2	10
Imperial Oil	Edmonton	Judy Creek	20 500	6	0.61	51	11.65	10	623	24	16.21	12	27.12	9
Coleman Collieries	Crowsnest	Vicary Creek	16 100	6	1.04	32	< 0.3	-	719	12	< 0.5	-	12.29	13
Coleman Collieries	Crowsnest	Tent Mountain	13 000	6	1.47	32	0.96	21	282	38	< 1.0	-	10.5	16
Cardinal River	Mountain Park	Cardinal River	7 520	6	0.47	57	< 0.6	-	473	23	1.71	45	9.11	15
BRITISH COLUMBIA														
B.C. Hydro	Ashcroft	Hat Creek	61 800	6	<1.0	-	9.18	13	235	33	< 1.0	-	22.4	9
B.C. Hydro	Ashcroft	Hat Creek*	29 600	6	<0.7	-	13.0	15	129	51	< 0.4	-	15.17	13
Tulameen	Tulameen	Tulameen	11 700	6	<0.6	-	< 0.7	-	97.4	46	263.0	6	19.62	10
B.P. Canada	Chetwynd	Sukunka	15 700	6	0.85	36	1.66	18	1 160	16	3.73	25	10.4	15
Denison Coal	E. Kootenay	Denison	8 600	7	<0.4	-	8.60	11	< 60	-	12.6	12	10.68	13
Byron Creek	E. Kootenay	Byron Creek	14 000	6	<1.0	-	0.58	52	674	21	< 1.0	-	10.9	15
Kaiser Resources	E. Kootenay	Kaiser (Seam No. 7)	17 000	6	0.67	46	0.4	-	386	16	40.7	8	12.87	13
Kaiser Resources	E. Kootenay	Elk View	18 900	6	<0.5	-	< 0.2	-	< 200	-	1.26	30	8.01	14
Kaiser Resources	E. Kootenay	Elk View*	15 900	6	<0.5	-	< 0.3	-	< 200	-	1.02	32	8.39	14
Fording Coal	E. Kootenay	Fording	15 400	6	1.34	32	< 0.4	-	< 200	-	< 0.9	-	11.1	14

* Clean coal samples

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

Company	Field	Mine	Chlorine ppm	% Err.	Chromium ppm	% Err.	Cobalt ppm	% Err.	Europium ppm	% Err.	Gadolinium ppm	% Err.	Hafnium ppm	% Err.
NOVA SCOTIA														
River Herbert	Joggins	River Herbert	2 382	16	33.6	11	5.67	13	0.52	18	<30	-	1.00	30
Thorburn	Pictou	Acadia	1 290	13	45.1	10	5.57	13	0.33	32	<90	-	0.91	46
Devco	Sydney	Lingan	1 450	11	5.09	37	2.00	18	< 0.1	-	<50	-	<0.2	-
Devco	Sydney	No. 26	859	12	< 3.0	-	2.74	16	< 0.1	-	<40	-	<0.2	-
Devco	Sydney	Prince	789	35	16.8	17	6.80	12	0.46	29	<20	-	0.41	52
NEW BRUNSWICK														
N.B. Electric Power	Minto	Minto	202	41	12.15	20	3.81	18	< 0.1	-	52.72	83	0.96	28
N.B. Coal	Minto	Minto	200	-	6.84	38	10.6	11	< 0.2	-	<90	-	1.11	24
SASKATCHEWAN														
Manitoba Power	Estevan	Estevan	< 200	-	< 4.0	-	1.56	24	< 0.5	-	<20	-	1.05	18
M&S Coal	Estevan	Bienfait	< 100	-	< 4.0	-	< 0.4	-	< 0.1	-	<50	-	1.37	23
M&S Coal	Estevan	Boundary Dam	< 200	-	< 4.0	-	1.72	21	< 0.1	-	<60	-	1.43	25
Sask. Power Corp.	Estevan	Boundary Dam	< 200	-	16.2	18	5.59	13	< 0.8	-	<20	-	1.03	22
Sask. Power Corp.	Estevan	Queen Eliz.	< 200	-	4.0	-	0.86	39	0.19	100	<20	-	0.66	27
Manalta	Estevan	Klimax	< 200	-	< 4.0	-	0.47	59	< 0.6	-	<20	-	1.01	23
Poplar River	Core Sample	Exploratory	< 500	-	< 5.0	-	1.16	30	< 0.3	-	<40	-	1.21	21
Poplar River	Core Sample	Exploratory	< 200	-	< 4.0	-	0.48	59	< 0.3	-	<40	-	1.39	20

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

Company	Field	Mine	Chlorine ppm	Chlorine % Err.	Chromium ppm	Chromium % Err.	Cobalt ppm	Cobalt % Err.	Europium ppm	Europium % Err.	Gadolinium ppm	Gadolinium % Err.	Hafnium ppm	Hafnium % Err.
ALBERTA														
Manalta	Sheerness	Roselyn	<200	-	< 3.0	-	0.84	36	< 0.1	-	< 70	-	0.91	30
McIntyre	Grande Cache	McIntyre	434	20	< 3.0	-	2.03	20	< 0.1	-	< 40	-	1.43	20
McIntyre	Grande Cache	McIntyre	355	50	< 5.0	-	1.53	23	0.18	60	< 30	-	1.19	18
Luscar Coal	Castor	Diplomat	<100	-	< 3.0	-	0.69	36	< 0.3	-	< 20	-	0.59	22
Manalta	Castor	Vesta	<200	-	< 3.0	-	0.52	46	< 0.3	-	< 20	-	1.01	19
Century Coals	Drumheller	Atlas	<200	-	< 3.0	-	0.42	51	< 0.5	-	< 20	-	0.62	36
Manalta	Pembina	Highvale	<400	-	< 3.0	-	1.39	27	< 0.4	-	< 30	-	0.99	25
Manalta	Pembina	Whitewood	<300	-	2.29	60	1.43	23	0.20	47	< 20	-	1.07	21
Sundance Mines	Edmonton	Sundance	<300	-	3.01	45	2.19	21	< 0.5	-	< 30	-	0.84	24
Imperial Oil	Edmonton	Judy Creek	<200	-	< 5.0	-	2.41	20	0.40	47	< 40	-	1.46	22
Coleman Collieries	Crowsnest	Vicary Creek	<200	-	9.21	24	2.27	20	< 0.2	-	< 50	-	1.95	18
Coleman Collieries	Crowsnest	Tent Mountain	<400	-	< 7.0	-	1.73	26	0.46	23	< 30	-	1.95	15
Cardinal River	Mountain Park	Cardinal River	<300	-	5.65	26	0.78	42	< 0.4	-	< 20	-	0.89	22
BRITISH COLUMBIA														
B.C. Hydro	Ashcroft	Hat Creek	< 0.3	-	37.3	12	9.85	11	< 0.2	-	<100	-	1.12	48
B.C. Hydro	Ashcroft	Hat Creek*	<100	-	30.5	11	8.56	11	< 0.2	-	< 70	-	3.15	20
Tulameen	Tulameen	Tulameen	<100	-	28.4	11	3.98	15	< 0.1	-	< 60	-	1.36	24
B.P. Canada	Chetwynd	Sukunka	497	40	22.8	14	2.22	22	0.15	40	< 40	-	1.00	26
Denison Coal	E. Kootenay	Denison	< 90	-	9.59	20	2.57	15	< 0.1	-	< 40	-	1.62	22
Byron Creek	E. Kootenay	Byron Creek	<200	-	< 5.0	-	0.65	47	0.46	41	< 30	-	1.46	22
Kaiser Resources	E. Kootenay	Kaiser (Seam No. 7)	<200	-	6.67	29	1.77	20	< 0.1	-	< 50	-	1.16	26
Kaiser Resources	E. Kootenay	Elk View	<400	-	4.06	37	1.49	12	0.98	62	< 30	-	1.17	19
Kaiser Resources	E. Kootenay	Elk View*	418	37	2.56	55	0.96	31	0.20	38	< 30	-	0.71	30
Fording Coal	E. Kootenay	Fording	<400	-	13.0	20	2.18	20	0.34	30	< 30	-	1.32	19

* Clean coal samples

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

Company	Field	Mine	Iodine		Iron		Lanthanum		Magnesium		Manganese		Potassium	
			ppm	% Err.	ppm	% Err.	ppm	% Err.	ppm	% Err.	ppm	% Err.	ppm	% Err.
NOVA SCOTIA														
River Herbert	Joggins	River Herbert	<30	-	37 900	7	11.1	21	6 210	50	219	25	10 900	6
Thorburn	Pictou	Acadia	<20	-	13 000	8	11.5	19	1 660	75	132	25	7 350	10
Devco	Sydney	Lingan	<10	-	8 130	9	2.28	55	519	75	96.9	25	360	29
Devco	Sydney	No. 26	<10	-	5 180	10	2.40	44	< 100	-	58.5	25	< 100	-
Devco	Sydney	Prince	<30	-	29 200	7	12.3	20	< 1 000	-	51.3	25	3 150	10
NEW BRUNSWICK														
N.B. Electric Power	Minto	Minto	<20	-	47 300	6	7.25	27	333	75	378	10	< 100	-
N.B. Coal	Minto	Minto	<20	-	77 100	6	5.04	45	175	75	526	25	< 200	-
SASKATCHEWAN														
Manitoba Power	Estevan	Estevan	<20	-	2 950	13	5.14	25	1 826	75	47.5	25	627	28
M&S Coal	Estevan	Bienfait	<10	-	3 090	12	6.53	20	1 170	75	24.3	25	< 200	-
M&S Coal	Estevan	Boundary Dam	<10	-	3 380	11	7.86	18	1 730	75	26.3	25	< 200	-
Sask. Power Corp.	Estevan	Boundary Dam	<20	-	3 990	12	19.1	14	2 870	60	34.9	25	1 770	25
Sask. Power Corp.	Estevan	Queen Eliz.	<20	-	3 890	11	3.10	36	2 400	60	106	25	822	18
Manalta	Estevan	Klimax	<22	-	3 610	12	7.28	19	3 720	50	48.2	25	< 700	-
Poplar River	Core Sample	Exploratory	<30	-	5 530	15	5.61	25	5 590	50	125	25	3 280	10
Poplar River	Core Sample	Exploratory	<30	-	4 700	11	6.05	22	4 410	50	127	25	2 370	13

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

Company	Field	Mine	Iodine ppm	Iodine % Err.	Iron ppm	Iron % Err.	Lanthanum ppm	Lanthanum % Err.	Magnesium ppm	Magnesium % Err.	Manganese ppm	Manganese % Err.	Potassium ppm	Potassium % Err.
ALBERTA														
Manalta	Sheerness	Roselyn	<20	-	4 740	12	4.64	24	1 270	75	113.0	25	< 100	-
McIntyre	Grande Cache	McIntyre	10.6	50	2 070	14	7.49	20	614	75	10.0	25	786	73
McIntyre	Grande Cache	McIntyre	<20	-	2 520	13	8.17	21	1 330	75	11.5	25	554	29
Luscar Coal	Castor	Diplomat	<20	-	2 700	12	1.45	65	1 690	75	26.9	25	585	20
Manalta	Castor	Vesta	<20	-	2 520	12	5.06	23	< 1 000	-	36.2	25	1 040	18
Century Coals	Drumheller	Atlas	<20	-	3 690	11	4.79	23	537	75	76.5	25	1 030	34
Manalta	Pembina	Highvale	<30	-	2 760	13	8.10	18	1 250	75	56.8	25	352	52
Manalta	Pembina	Whitewood	<20	-	4 570	11	9.56	17	1 470	75	144.0	25	719	19
Sundance Mines	Edmonton	Sundance	<30	-	5 070	10	12.9	15	3 050	50	82.5	25	360	63
Imperial Oil	Edmonton	Judy Creek	<30	-	4 350	11	15.28	14	903	75	141.0	25	1 460	18
Coleman Collieries	Crowsnest	Vicary Creek	<10	-	1 850	17	8.45	22	692	75	21.7	25	< 200	-
Coleman Collieries	Crowsnest	Tent Mountain	<30	-	2 140	16	10.7	22	2 300	60	20.1	25	584	18
Cardinal River	Mountain Park	Cardinal River	<20	-	283	15	5.75	24	2 416	60	15.1	25	489	33
BRITISH COLUMBIA														
B.C. Hydro	Ashcroft	Hat Creek	<10	-	16 400	8	3.52	88	3 280	50	172.0	25	3 060	44
B.C. Hydro	Ashcroft	Hat Creek*	<10	-	9 810	9	< 4.0	-	1 560	75	41.2	25	< 100	-
Tulameen	Tulameen	Tulameen	<10	-	9 610	8	11.8	16	242	75	53.5	25	1 750	45
B.P. Canada	Chetwynd	Sukunka	<30	-	3 610	14	6.59	23	1 040	75	18.4	25	3 370	8
Denison Coal	E. Kootenay	Denison	<10	-	3 550	11	7.83	19	< 1 000	-	10.7	25	< 200	-
Byron Creek	E. Kootenay	Byron Creek	<30	-	2 380	16	< 4.0	-	4 860	50	32.7	25	612	29
Kaiser Resources	E. Kootenay	Kaiser (Seam No. 7)	<10	-	3 610	12	< 4.0	-	100	75	19.5	25	< 100	-
Kaiser Resources	E. Kootenay	Elk View	<20	-	540	34	11.3	20	585	75	13.4	25	1 160	12
Kaiser Resources	E. Kootenay	Elk View*	<20	-	1 490	18	< 3.0	-	515	75	20.8	25	460	19
Fording Coal	E. Kootenay	Fording	<30	-	2 060	17	8.37	22	< 1 000	-	23.5	25	1 165	13

* Clean coal samples

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

Company	Field	Mine	Samarium		Scandium		Selenium		Sodium		Strontium		Tantalum	
			ppm	% Err.	ppm	% Err.	ppm	% Err.	ppm	% Err.	ppm	% Err.	ppm	% Err.
NOVA SCOTIA														
River Herbert	Joggins	River Herbert	2.65	8	0.1	-	< 5.0	-	1 390	6	<500	-	< 0.9	-
Thorburn	Pictou	Acadia	2.04	9	5.75	6	< 5.0	-	517	6	<100	-	< 1.0	-
Devco	Sydney	Lingan	0.31	11	0.52	30	< 3.0	-	143	8	< 70	-	< 0.4	-
Devco	Sydney	No. 26	0.41	22	0.58	10	< 3.0	-	45.0	10	< 70	-	< 0.6	-
Devco	Sydney	Prince	1.60	10	3.18	7	3.46	68	355	6	174	50	< 1.0	-
NEW BRUNSWICK														
N.B. Electric	Minto	Minto	2.34	8	2.00	8	4.89	50	389	19	<100	-	< 1.0	-
N.B. Coal	Minto	Minto	2.29	9	10.5	8	10.9	26	192	19	<100	-	< 1.0	-
SASKATCHEWAN														
Manitoba Power	Estevan	Estevan	0.10	98	1.44	8	< 4.0	-	4 090	6	414	50	< 0.7	-
M&S Coal Co.	Estevan	Bienfait	0.75	14	1.48	7	< 4.0	-	6 820	7	170	32	< 0.5	-
M&S Coal Co.	Estevan	Boundary Dam	1.09	11	1.65	7	< 3.0	-	6 740	7	162	33	< 0.7	-
Sask. Power Corp.	Estevan	Boundary Dam	3.46	8	4.34	7	< 4.0	-	7 560	6	240	74	< 0.9	-
Sask. Power Corp.	Estevan	Queen Eliz.	0.09	100	1.16	8	< 3.0	-	1 820	6	<400	-	0.30	69
Manalta	Estevan	Klimax	0.82	13	1.33	8	< 3.0	-	4 660	6	681	33	< 0.6	-
Poplar River	Core Sample	Exploratory	0.06	100	1.53	8	< 3.0	-	1 090	6	<600	-	0.14	100
Poplar River	Core Sample	Exploratory	0.06	100	1.37	8	< 3.0	-	994	6	<600	-	< 0.6	-

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

Company	Field	Mine	Samarium ppm	% Err.	Scandium ppm	% Err.	Selenium ppm	% Err.	Sodium ppm	% Err.	Strontium ppm	% Err.	Tantalum ppm	% Err.
ALBERTA														
Manalta	Sheerness	Roselyn	0.78	12	1.49	8	<3.0	-	1 150	8	<100	-	<0.7	-
McIntyre	Grande Cache	McIntyre	0.18	100	2.32	7	<3.0	-	570	8	88.9	46	<0.9	-
McIntyre	Grande Cache	McIntyre	1.67	21	2.88	7	<3.0	-	9 150	6	<500	-	<0.6	-
Luscar Coal	Castor	Diplomat	1.21	13	0.92	8	<3.0	-	1 370	6	217	74	<0.3	-
Manalta	Castor	Vesta	0.67	15	0.95	9	<3.0	-	3 150	6	230	68	<0.5	-
Century Coals	Drumheller	Atlas	1.03	11	1.09	8	<3.0	-	3 830	6	374	51	<0.5	-
Manalta	Pembina	Highvale	0.18	57	1.51	8	<2.0	-	2 470	6	<500	-	<1.0	-
Manalta	Pembina	Whitewood	1.11	11	1.67	8	<3.0	-	228	7	<400	-	<1.0	-
Sundance Mines	Edmonton	Sundance	2.00	9	1.96	7	<3.0	-	3 180	6	<500	-	<0.8	-
Imperial Oil	Edmonton	Judy Creek	3.02	8	3.20	7	<3.0	-	1 910	6	<600	-	<0.7	-
Coleman Collieries	Crowsnest	Vicary Creek	1.40	11	4.80	6	<4.0	-	300	14	170	26	<0.6	-
Coleman Collieries	Crowsnest	Tent Mountain	2.19	11	6.21	6	<4.0	-	241	6	<500	-	<0.8	-
Cardinal River	Mountain Park	Cardinal River	0.87	17	2.04	7	<4.0	-	1 000	6	<400	-	<0.7	-
BRITISH COLUMBIA														
B.C. Hydro	Ashcroft	Hat Creek	2.48	9	11.6	6	<5.0	-	680	8	<200	-	<1.0	-
B.C. Hydro	Ashcroft	Hat Creek*	90.1	10	7.81	6	<5.0	-	787	9	< 90	-	<0.8	-
Tulameen	Tulameen	Tulameen	1.76	9	2.65	7	<4.0	-	165	11	< 90	-	<0.9	-
B.P. Canada	Chetwynd	Sukunka	0.17	63	2.58	7	2.49	71	786	6	<600	-	<0.9	-
Denison Coal	E. Kootenay	Denison	0.88	13	2.24	11	<3.0	-	448	8	65.5	57	<0.4	-
Byron Creek	E. Kootenay	Byron Creek	0.10	100	4.42	7	<4.0	-	810	6	<600	-	<0.7	-
Kaiser Resources	E. Kootenay	Kaiser (Seam No. 7)	1.23	11	3.56	7	<4.0	-	84.7	14	< 70	-	<0.5	-
Kaiser Resources	E. Kootenay	Elk View	0.06	100	3.27	6	<3.0	-	42.8	9	<500	-	<0.4	-
Kaiser Resources	E. Kootenay	Elk View*	1.00	12	3.80	7	<3.0	-	44.8	8	<500	-	<0.4	-
Fording Coal	E. Kootenay	Fording	1.41	11	3.94	7	<4.0	-	57.8	9	<500	-	<0.7	-

* Clean coal samples

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

Company	Field	Mine	Terbium ppm	% Err.	Thorium ppm	% Err.	Titanium ppm	% Err.	Uranium ppm	% Err.	Vanadium ppm	% Err.	Ytterbium ppm	% Err.
NOVA SCOTIA														
River Herbert	Joggins	River Herbert	<0.9	-	2.95	11	1 160	16	1.78	10	49.1	8	0.99	32
Thorburn	Pictou	Acadia	<1.0	-	3.62	9	2 920	16	1.24	10	58.0	10	0.89	34
Devco	Sydney	Lingan	<0.4	-	0.30	42	< 400	-	0.20	10	3.88	39	<0.2	-
Devco	Sydney	No. 26	<0.4	-	0.20	53	340	53	<0.1	-	5.34	21	<0.3	-
Devco	Sydney	Prince	<1.0	-	2.03	15	644	23	0.96	10	9.13	37	0.86	35
NEW BRUNSWICK														
N.B. Electric Power	Minto	Minto	<0.8	-	1.16	20	1 670	26	1.18	10	26.98	12	0.94	33
N.B. Coal	Minto	Minto	<0.9	-	1.10	24	1 270	37	1.55	10	31.6	12	0.98	34
SASKATCHEWAN														
Manitoba Power	Estevan	Estevan	<0.5	-	2.14	14	508	24	1.48	10	7.56	18	<0.4	-
M&S Coal	Estevan	Bienfait	<0.4	-	3.23	11	1 730	20	2.91	10	5.01	35	<0.3	-
M&S Coal Co.	Estevan	Boundary Dam	<0.5	-	2.70	12	1 650	21	1.77	10	7.93	23	0.62	32
Sask. Power Corp.	Estevan	Boundary Dam	<0.8	-	1.99	15	421	24	2.55	10	22.4	10	1.93	20
Sask. Power Corp.	Estevan	Queen Eliz.	<0.5	-	1.85	14	162	53	0.78	10	4.65	26	0.28	56
Manalta	Estevan	Klimax	<0.5	-	3.68	10	626	21	1.79	10	4.74	28	0.21	90
Poplar River	Core Sample	Exploratory	<0.3	-	3.36	11	681	22	2.35	10	17.2	14	0.26	71
Poplar River	Core Sample	Exploratory	<0.6	-	3.92	10	678	23	2.12	10	17.5	13	<0.3	-

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

Company	Field	Mine	Terbium ppm	Terbium % Err.	Thorium ppm	Thorium % Err.	Titanium ppm	Titanium % Err.	Uranium ppm	Uranium % Err.	Vanadium ppm	Vanadium % Err.	Ytterbium ppm	Ytterbium % Err.
ALBERTA														
Manalta	Sheerness	Roselyn	<0.4	-	1.82	14	500	-	1.11	10	4.72	32	0.36	42
McIntyre	Grande Cache	McIntyre	<0.5	-	1.51	18	1 550	17	1.72	10	26.3	11	0.71	35
McIntyre	Grande Cache	McIntyre	<0.6	-	1.55	18	654	19	1.55	10	26.9	9	0.96	27
Luscar Coal	Castor	Diplomat	<0.3	-	1.48	15	220	34	0.49	10	2.83	31	<0.3	-
Manalta	Castor	Vesta	<0.5	-	2.11	12	161	48	0.87	10	0.94	78	0.36	49
Century Coals	Drumheller	Atlas	<0.4	-	2.88	10	213	41	1.09	10	2.11	46	0.87	23
Manalta	Pembina	Highvale	<0.5	-	2.96	10	451	27	1.73	10	4.09	31	0.70	31
Manalta	Pembina	Whitewood	<0.5	-	2.72	11	556	23	1.45	10	9.47	17	0.56	38
Sundance Mines	Edmonton	Sundance	<0.5	-	2.55	10	403	28	1.47	10	9.29	17	1.43	18
Imperial Oil	Edmonton	Judy Creek	<0.6	-	6.17	9	942	17	1.55	10	10.62	16	1.31	22
Coleman Collieries	Crowsnest	Vicary Creek	<0.7	-	2.93	12	2 520	14	2.02	10	33.8	11	1.09	31
Coleman Collieries	Crowsnest	Tent Mountain	<0.9	-	4.82	10	989	15	1.95	10	62.9	7	1.19	31
Cardinal River	Mountain Park	Cardinal River	<0.6	-	2.22	11	420	23	1.15	10	11.8	12	0.13	100
BRITISH COLUMBIA														
B.C. Hydro	Ashcroft	Hat Creek	<1.0	-	2.54	14	5.5	12	1.89	10	93.5	8	1.90	20
B.C. Hydro	Ashcroft	Hat Creek*	<1.0	-	1.45	16	3 010	16	1.19	10	108.0	8	1.37	27
Tulameen	Tulameen	Tulameen	<0.7	-	2.19	13	1 600	21	1.49	10	34.3	10	1.04	27
B.P. Canada	Chetwynd	Sukunka	<0.6	-	1.79	15	688	22	1.49	10	68.8	8	0.30	69
Denison Coal	E. Kootenay	Denison	<0.5	-	1.56	14	983	25	1.57	10	23.4	12	0.52	40
Byron Creek	E. Kootenay	Byron Creek	<0.9	-	1.26	23	1 110	15	0.97	10	18.6	12	0.66	50
Kaiser Resources	E. Kootenay	Kaiser (Seam No. 7)	<0.7	-	1.62	16	2 520	13	1.22	10	46.4	9	0.95	28
Kaiser Resources	E. Kootenay	Elk View	<0.5	-	1.35	15	945	15	0.95	10	23.8	10	0.42	49
Kaiser Resources	E. Kootenay	Elk View*	<0.6	-	1.45	15	733	19	0.62	10	19.4	11	0.69	32
Fording Coal	E. Kootenay	Fording	<0.7	-	1.97	15	1 040	15	1.23	10	39.4	9	1.17	27

* Clean coal samples

TABLE 4 CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY PLASMA EMISSION SPECTROMETRY

Company	Field	Mine	Aluminum	Barium	Beryllium	Boron	Cadmium	Calcium	Chromium	Cobalt
NOVA SCOTIA										
River Herbert	Joggins	River Herbert	29 950	211.2	0.9	-	-	6 488	56.4	28.2
Thorburn	Pictou	Acadia	42 760	196.7	0.9	1 872	-	1 929	50.0	3.8
Devco	Sydney	Lingan	2 640	13.6	-	-	-	668.6	20.3	22.7
Devco	Sydney	No. 26	1 590	15.9	-	149.1	-	188.8	4.0	-
Devco	Sydney	Prince	18 080	93.0	1.1	-	-	904.1	41.1	31.6
NEW BRUNSWICK										
N.B. Electric Power	Minto	Minto	9 382	43.1	1.5	-	-	5 511	25.6	26.4
N.B. Coal	Minto	Minto	9 083	33.9	1.7	-	-	10 970	20.2	32.7
SASKATCHEWAN										
Manitoba Power	Estevan	Estevan	11 440	841.4	-	850.6	-	13 370	7.3	5.5
M&S Coal Co.	Estevan	Bienfait	13 930	1 213	-	1 241	-	12 510	7.6	3.8
M&S Coal Co.	Estevan	Boundary Dam	16 440	1 086	0.5	1 163	-	14 610	9.9	-
			16 430	1 080	-	1 540	-	12 960	9.5	-
Sask. Power Corp.	Estevan	Boundary Dam	15 180	755.0	1.8	1 064	-	11 430	20.3	3.9
Sask. Power Corp.	Estevan	Queen Eliz.	10 150	430.8	-	741.0	-	3 542	4.0	-
Manalta	Estevan	Klimax	14 710	253.9	-	1 340	-	16 490	6.0	-
Poplar River	Core Sample	Exploratory	21 640	543.0	-	1 858	7.7	7 240	14.8	-
Poplar River	Core Sample	Exploratory	15 910	372.9	-	1 415	8.8	15 520	10.5	-

TABLE 4 CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY PLASMA EMISSION SPECTROMETRY (cont'd.)

Company	Field	Mine	Aluminum	Barium	Beryllium	Boron	Cadmium	Calcium	Chromium	Cobalt
ALBERTA										
Manalta	Sheerness	Roselyn	17 760	278.6	-	912.3	-	11 030	5.6	-
McIntyre	Grande Cache	McIntyre	11 160	328.4	-	469.8	-	1 944	8.6	-
McIntyre	Grande Cache	McIntyre	11 480	400.5	-	427.3	7.5	1 801	10.4	-
Luscar Coal	Castor	Diplomat	7 078	412.5	-	849.7	-	9 468	1.9	7.6
Manalta	Castor	Vesta	11 280	508.7	-	833.6	-	8 132	0.9	-
Century Coals	Drumheller	Atlas	13 530	568.9	-	1 225	-	7 960	3.0	-
Manalta	Pembina	Highvale	20 930	589.0	0.4	1 413	7.9	12 270	4.4	-
Manalta	Pembina	Whitewood	15 590	415.0	-	1 057	7.0	14 100	7.3	-
Sundance Mines	Edmonton	Sundance	15 420	597.5	0.6	916.9	-	12 760	4.8	-
Imperial Oil	Edmonton	Judy Creek	29 050	528.6	1.3	-	-	12 360	16.0	16.2
Coleman Collieries	Crowsnest	Vicary Creek	14 320	727.3	-	1 004	-	2 809	7.9	10.2
Coleman Collieries	Crowsnest	Tent Mountain	18 660	557.9	0.5	648.4	-	3 825	13.0	-
Cardinal River	Mountain Park	Cardinal River	11 450	473.9	-	652.6	-	4 618	6.4	-
BRITISH COLUMBIA										
B.C. Hydro	Ashcroft	Hat Creek	77 240	343.1	0.8	2 455	6.6	7 942	62.6	14.2
B.C. Hydro	Ashcroft	Hat Creek*	32 000	115.8	0.6	1 688	7.1	5 410	42.0	11.5
Tulameen	Tulameen	Tulameen	12 480	88.5	1.0	-	-	1 200	35.8	22.1
B.P. Canada	Chetwynd	Sukunka	14 470	925.2	-	827.5	-	3 579	22.5	2.8
Denison Coal	E. Kootenay	Denison	8 460	697.2	-	-	-	2 613	18.5	12.4
Byron Creek	E. Kootenay	Byron Creek	25 430	702.9	-	1 152	8.3	6 587	8.2	-
Kaiser Resources	E. Kootenay	Kaiser (Seam No. 7)	14 050	324.8	-	633.3	8.2	1 725	11.3	-
Kaiser Resources	E. Kootenay	Elk View	24 520	104.4	-	790.2	8.6	2 538	11.9	-
Kaiser Resources	E. Kootenay	Elk View*	13 380	77.1	-	544.7	8.5	1 945	8.0	-
Fording Coal	E. Kootenay	Fording	14 320	71.8	-	963.3	-	992.1	11.0	-

* Clean coal samples

TABLE 4 CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY PLASMA EMISSION SPECTROMETRY (cont'd.)

Company	Field	Mine	Copper	Iron	Lead	Magnesium	Manganese	Molybdenum	Nickel	Phosphorus
NOVA SCOTIA										
River Herbert	Joggins	River Herbert	23.9	30 800	52.6	2 638	208.4	178.4	25.3	591.3
Thorburn	Pictou	Acadia	16.9	15 010	11.4	1 749	102.6	-	26.6	209.1
Devco	Sydney	Lingan	13.6	2 373	10.9	216.8	102.5	145.2	8.2	-
Devco	Sydney	No. 26	3.6	2 909	1.8	66.2	33.6	-	4.5	-
Devco	Sydney	Prince	19.5	29 320	52.7	630.3	49.2	149.2	28.1	245.8
NEW BRUNSWICK										
N.B. Electric Power	Minto	Minto	24.4	49 190	3.6	396.2	335.2	209.5	21.9	792.5
N.B. Coal	Minto	Minto	32.3	89 960	1.9	423.4	454.2	192.4	34.6	1 116.0
SASKATCHEWAN										
Manitoba Power	Estevan	Estevan	10.2	1 005	12.8	2 426	33.9	-	7.3	164.8
M&S Coal Co.	Estevan	Bienfait	12.2	3 297	7.6	2 132	18.8	-	6.6	-
M&S Coal Co.	Estevan	Boundary Dam	14.5	3 854	11.5	2 682	19.8	-	-	86.5
			13.4	3 793	9.4	2 601	17.7	-	-	65.7
Sask. Power Corp.	Estevan	Boundary Dam	17.8	4 031	9.9	2 622	27.5	-	21.7	78.8
Sask. Power Corp.	Estevan	Queen Eliz.	5.6	4 442	7.7	976.5	110.1	-	4.8	153.2
Manalta	Estevan	Klimax	8.6	4 338	5.6	2 717	38.9	-	-	224.9
Poplar River	Core Sample	Exploratory	12.4	6 598	13.4	5 124	112.0	-	6.7	-
Poplar river	Core Sample	Exploratory	14.5	4 675	17.6	4 334	98.6	-	6.8	-

TABLE 4 CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY PLASMA EMISSION SPECTROMETRY (cont'd.)

Company	Field	Mine	Copper	Iron	Lead	Magnesium	Manganese	Molybdenum	Nickel	Phosphorus
ALBERTA										
Manalta	Sheerness	Roselyn	3.6	4 347	5.6	1 440	154.2	-	-	84.1
McIntyre	Grande Cache	McIntyre	10.1	1 879	3.7	265.1	5.0	-	4.7	344.2
McIntyre	Grande Cache	McIntyre	9.8	432.6	5.0	243.8	3.8	-	7.5	318.4
Luscar Coal	Castor	Diplomat	5.2	2 438	3.8	815.4	25.1	-	-	333.4
Manalta	Castor	Vesta	5.5	3 171	1.9	482.4	46.8	-	-	457.2
Century Coals	Drumheller	Atlas	9.2	3 832	4.0	746.7	102.7	-	-	632.1
Manalta	Pembina	Highvale	4.4	3 418	7.1	834.5	97.3	-	6.2	-
Manalta	Pembina	Whitewood	4.8	4 996	19.4	1 542	-	-	9.7	-
Sundance Mines	Edmonton	Sundance	9.5	5 250	5.5	730.5	86.8	-	-	73.4
Imperial Oil	Edmonton	Judy Creek	9.7	4 547	10.8	1 065	151.6	99.2	9.0	90.2
Coleman Collieries	Crowsnest	Vicary Creek	16.3	1 795	13.0	598.0	12.1	18.6	4.7	678.9
Coleman Collieries	Crowsnest	Tent Mountain	16.2	1 913	11.2	700.7	10.4	-	5.6	578.5
Cardinal River	Mountain Park	Cardinal River	8.0	2 318	7.4	923.6	6.4	-	-	195.5
BRITISH COLUMBIA										
B.C. Hydro	Ashcroft	Hat Creek	61.4	20 560	3.8	3 933	177.2	-	50.2	75.8
B.C. Hydro	Ashcroft	Hat Creek*	58.7	9 989	7.1	2 413	29.4	-	37.1	-
Tulameen	Tulameen	Tulameen	36.0	10 460	1.9	561.4	54.3	105.6	21.1	105.6
B.P. Canada	Chetwynd	Sukunka	8.8	3 926	5.6	1 249	7.7	-	13.2	197.3
Denison Coal	E. Kootenay	Denison	29.9	4 568	5.7	1 249	7.5	76.3	13.4	295.7
Byron Creek	E. Kootenay	Byron Creek	12.5	2 708	5.5	1 354	15.9	-	-	304.0
Kaiser Resources	E. Kootenay	Kaiser (Seam No. 7)	15.1	3 769	2.7	157.9	9.6	-	6.4	793.9
Kaiser Resources	E. Kootenay	Elk View	9.0	803.6	5.7	373.6	4.5	-	-	162.8
Kaiser Resources	E. Kootenay	Elk View*	9.3	1 499	7.6	10.6	-	-	341.6	-
Fording Coal	E. Kootenay	Fording	11.8	2 087	3.7	262.1	16.0	-	7.5	308.9

* Clean coal samples

TABLE 4 CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY PLASMA EMISSION SPECTROMETRY (cont'd.)

Company	Field	Mine	Potassium	Silver	Sodium	Strontium	Thorium	Titanium	Vanadium	Zinc	Zirconium
NOVA SCOTIA											
River Herbert	Joggins	River Herbert	9 163	1.1	-	73.7	4.7	1 005.0	55.4	49.8	53.6
Thorburn	Pictou	Acadia	7 156	-	1 806	121.6	1.9	901.8	59.7	45.6	38.8
Devco	Sydney	Lingan	290.3	2.3	-	10.4	2.7	127.0	5.3	11.8	104.3
Devco	Sydney	No. 26	72.3	-	361.4	4.8	-	77.3	3.3	5.4	2.6
Devco	Sydney	Prince	3 318	1.0	-	130.8	6.1	677.7	28.3	47.4	33.4
NEW BRUNSWICK											
N.B. Electric Power	Minto	Minto	1 694	0.7	-	43.8	3.6	519.2	21.0	26.4	43.1
N.B. Coal Ltd.	Minto	Minto	1 068	1.9	-	45.9	2.9	510.0	25.8	44.3	53.3
SASKATCHEWAN											
Manitoba Power	Estevan	Estevan	805.7	-	-	380.9	6.4	564.9	9.0	54.0	33.9
M&S Coal Co.	Estevan	Bienfait	691.6	0.2	-	401.7	6.6	891.5	9.0	138.3	41.2
M&S Coal Co.	Estevan	Boundary Dam	797.8	-	7 209	456.6	-	747.8	10.9	89.4	52.1
			732.3	1.9	7 323	456.3	-	745.5	10.7	9.4	334.2
Sask. Power Corp.	Estevan	Boundary Dam	1 459	0.4	8 279	426.8	1.0	592.4	31.7	48.3	64.2
Sask. Power Corp.	Estevan	Queen Eliz.	813.8	-	-	201.1	1.9	282.4	5.1	6.7	303.5
Manalta	Estevan	Klimax	75.0	-	5 435	551.9	2.8	874.3	7.5	11.2	41.4
Poplar River	Core Sample	Exploratory	2 988	-	2 203	259.5	2.9	688.6	20.1	16.3	58.4
Poplar River	Core Sample	Exploratory	1 972	0.2	1 855	217.7	2.9	528.1	15.2	22.5	48.2

TABLE 4 CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY PLASMA EMISSION SPECTROMETRY (cont'd.)

Company	Field	Mine	Potassium	Silver	Sodium	Strontium	Thorium	Titanium	Vanadium	Zinc	Zirconium
ALBERTA											
Manalta	Sheerness	Roselyn	1 440	-	1 776	211.3	1.9	388.9	6.3	5.6	256.1
McIntyre	Grande Cache	McIntyre	241.9	-	837.2	142.3	-	654.9	26.9	14.9	35.1
McIntyre	Grande Cache	McIntyre	318.4	-	670.2	163.4	-	628.4	31.1	50.3	33.8
Luscar Coal	Castor	Diplomat	743.0	2.7	-	254.3	6.7	194.3	3.0	10.5	24.7
Manalta	Castor	Vesta	846.2	-	3 891	374.5	-	216.9	2.8	4.9	37.4
Century Coals	Drumheller	Atlas	1 007	0.9	-	355.6	5.0	288.4	4.3	110.6	47.7
Manalta	Pembina	Highvale	362.1	-	3 709	145.7	3.5	538.7	6.5	15.9	64.3
Manalta	Pembina	Whitewood	660.9	-	969.2	62.0	3.5	500.5	9.1	22.9	49.0
Sundance Mines	Edmonton	Sundance	266.2	-	3 212	144.1	1.8	509.4	10.5	9.2	47.4
Imperial Oil	Edmonton	Judy Creek	775.8	0.8	-	133.5	9.0	1 001	15.2	14.4	117.3
Coleman Collieries	Crowsnest	Vicary Creek	734.7	0.8	-	200.0	6.5	1 116	34.9	22.3	52.7
Coleman Collieries	Crowsnest	Tent Mountain	307.9	-	373.2	223.9	-	1 316	44.4	53.2	66.6
Cardinal River	Mountain Park	Cardinal River	204.8	-	-	128.5	0.9	530.7	14.9	37.2	33.0
BRITISH COLUMBIA											
B.C. Hydro	Ashcroft	Hat Creek	3 412	-	2 654	124.1	3.8	3 080	125.1	58.8	134.6
B.C. Hydro	Ashcroft	Hat Creek*	1 538	3.1	1 945	67.6	-	1 768	128.2	35.4	476.4
Tulameen	Tulameen	Tulameen	2 774	1.4	0	23.1	2.9	838.8	38.9	26.9	71.2
B.P. Canada	Chetwynd	Sukunka	3 250	-	1 409	119.3	-	741.1	66.6	29.1	21.2
Denison Coal	E. Kootenay	Denison	419.6	3.3	-	100.1	1.9	477.8	24.6	17.2	36.4
Byron Creek	E. Kootenay	Byron Creek	359.3	-	1 290	234.0	-	1 621	29.2	10.1	59.1
Kaiser Resources	E. Kootenay	Kaiser (Seam No. 7)	428.9	-	365.0	130.5	-	756.4	40.0	18.2	37.1
Kaiser Resources	E. Kootenay	Elk View	785.4	-	287.4	26.1	-	1 226	27.1	88.1	38.0
Kaiser Resources	E. Kootenay	Elk View*	161.3	-	-	22.7	-	780	22.8	11.4	32.9
Fording Coal	E. Kootenay	Fording	589.7	-	-	36.2	-	864.8	38.8	19.7	32.9

* Clean coal samples

TABLE 5 CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY ATOMIC ABSORPTION SPECTROMETRY

Company	Field	Mine	Copper	Iron	Lead	Manganese	Zinc
NOVA SCOTIA							
Devco	Sydney	No. 26	6.7	3 250	0.9	61.8	10.5
SASKATCHEWAN							
Poplar River	Core Sample	Exploratory	18.6	5 749	20.5	107.4	19.5
ALBERTA							
McIntyre	Grande Cache	McIntyre	10.9	1 885	9.2	5.9	44.4
Coleman Collieries	Crowsnest	Tent Mountain	17.7	1 987	13.9	12.1	28.9
BRITISH COLUMBIA							
B.C. Hydro	Ashcroft	Hat Creek*	68.2	21 133	19.9	183.9	56.9
B.C. Hydro	Ashcroft	Hat Creek	62.8	10 784	12.4	31.8	56.9
B.P. Canada	Chetwynd	Sukunka	9.4	4 245	8.4	8.5	28.2
Byron Creek	E. Kootenay	Byron Creek	13.8	2 929	11.0	19.34	10.1
Kaiser Resources	E. Kootenay	Kaiser (Seam No. 7)	15.5	3 832	6.3	11.0	15.6
Kaiser Resources	E. Kootenay	Elk View*	8.62	729	5.7	4.5	14.4

* Clean coal samples

TABLE 6 COMPARISON OF TRACE ELEMENT CONCENTRATIONS (IN PPM) AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS AND PLASMA EMISSION SPECTROMETRY

Company	Field	Mine	Aluminum NAA/PES	Barium NAA/PES	Chromium NAA/PES	Cobalt NAA/PES	Iron NAA/PES	Magnesium NAA/PES
NOVA SCOTIA								
River Herbert	Joggins	River Herbert	25 300/29 950	< 200/211.2	33.6/56.4	5.67/28.2	37 900/30 800	6 210/2 638
Thorburn	Pictou	Acadia	43 400/42 760	259/196.7	45.1/50.0	5.57/3.8	13 000/15 010	1 660/1 749
Devco	Sydney	Lingan	1 940/2 640	< 70/13.6	5.09/20.3	2.00/22.7	8 130/8 373	519/216.8
Devco	Sydney	No. 26	2 690/1 590	< 60/15.9	3.02/4.0	2.74/-	5 180/2 909	100/66.2
Devco	Sydney	(Mixture)	14 400/14 300	< 100/64.1	14.8/26.9	2.71/14.4	13 372/14 510	515/1 054
Devco	Sydney	Prince	20 500/18 080	93.7/93.0	16.8/41.1	6.80/31.6	29 200/29 320	1 000/630.0
NEW BRUNSWICK								
N.B. Electric Power	Minto	Minto	10 100/9 382	< 100/43.1	12.15/25.6	3.81/26.4	47 300/49 190	333/396.2
N.B. Coal	Minto	Minto	10 700/9 083	< 100/33.9	6.84/20.2	10.6/32.7	77 100/89 960	175/423.4
SASKATCHEWAN								
Manitoba Power	Estevan	Estevan	12 100/11 440	1 090/841.4	< 4.0/7.3	1.56/5.5	2 950/1 005	1 826/2 426
M&S Coal	Estevan	Bienfait	11 800/13 930	1 120/1 213	< 4.0/7.6	< 0.4/3.8	3 090/3 297	1 170/2 132
M&S Coal	Estevan	Boundary Dam	14 000/16 440	832/1 086	< 4.0/9.9	1.72/-	3 380/3 854	1 730/2 682
Sask. Power Corp.	Estevan	Boundary Dam	8 570/15 180	594/755.0	16.22/20.3	5.59/3.9	3 990/4 031	2 870/2 622
Sask. Power Corp.	Estevan	Queen Eliz.	10 500/10 150	462/430.8	< 4.0/4.0	0.86/-	3 890/4 442	2 400/976.5
Manalta	Estevan	Klimax	14 000/14 710	1 190/253.9	< 4.0/6.0	0.47/-	3 610/4 338	3 720/2 717
Poplar River	Core Sample	Exploratory	22 400/21 640	675/543.0	< 5.0/14.8	1.16/-	5 530/6 598	5 590/5 124
Poplar River	Core Sample	Exploratory	18 500/15 910	413/372.9	< 4.0/10.5	0.48/-	4 700/4 675	4 410/4 334

TABLE 6 COMPARISON OF TRACE ELEMENT CONCENTRATIONS (IN PPM) AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS AND PLASMA EMISSION SPECTROMETRY (cont'd.)

Company	Field	Mine	Aluminum NAA/PES	Barium NAA/PES	Chromium NAA/PES	Cobalt NAA/PES	Iron NAA/PES	Magnesium NAA/PES
ALBERTA								
Manalta	Sheerness	Roselyn	13 200/17 760	166/278.6	< 3.0/5.6	0.84/-	4 740/4 347	1 270/1 440
McIntyre	Grande Cache	McIntyre	10 800/11 160	301/328.4	< 3.0/8.6	2.03/-	2 070/1 879	614/265.1
McIntyre	Grande Cache	McIntyre	12 100/11 480	363/400.5	< 5.0/10.4	1.53/-	2 520/432.6	1 330/243.8
Luscar Coal	Castor	Diplomat	7 640/7 078	308/412.5	< 3.0/1.9	0.69/7.6	2 700/2 438	1 690/815.4
Manalta	Castor	Vesta	10 100/11 280	558/508.7	< 3.0/0.9	0.52/-	2 520/3 171	< 1 000/482.4
Century Coals	Drumheller	Atlas	12 800/13 530	395/568.9	< 3.0/3.0	0.42/-	3 690/3 832	537/746.7
Manalta	Pembina	Highvale	20 700/20 930	617/589.9	< 3.0/4.4	1.39/-	2 760/3 418	1 250/834.5
Manalta	Pembina	Whitewood	15 300/15 950	264/415.0	2.29/7.3	1.43/-	4 570/4 996	1 470/1 542
Sundance Mines	Edmonton	Sundance	14 700/15 420	570/597.5	3.01/4.8	2.15/-	5 070/5 250	3 050/730.5
Imperial Oil	Edmonton	Judy Creek	20 500/29 050	623/528.6	< 5.0/16.0	2.41/16.2	4 350/4 547	903/1 065
Coleman Collieries	Crowsnest	Vicary Creek	16 100/14 320	719/727.3	9.21/7.9	2.27/10.2	1 850/1 795	6 92/598.0
Coleman Collieries	Crowsnest	Tent Mountain	13 000/18 660	282/557.9	< 7.0/13.0	1.73/-	2 140/1 913	2 300/700.7
Cardinal River	Mountain Park	Cardinal river	7 520/11 450	473/473.9	5.65/6.4	0.78/-	283/2 318	2 416/923.6
BRITISH COLUMBIA								
B.C. Hydro	Ashcroft	Hat Creek	61 800/77 240	235/343.1	37.3/62.6	9.85/14.2	16 400/20 560	3 280/3 933
B.C. Hydro	Ashcroft	Hat Creek*	29 600/32 000	129/115.8	30.5/42.0	8.56/11.5	9 810/9 989	1 560/2 413
Tulameen	Tulameen	Tulameen	11 700/12 480	97.4/88.5	28.4/35.8	3.90/22.1	9 610/10 460	242/561.4
B.P. Canada	Chetwynd	Sukunka	15 700/14 470	1 160/925.5	22.8/22.5	2.22/2.8	3 610/3 926	1 040/1 249
Denison Coal	E. Kootenay	Denison	8 600/8 460	< 60/697.2	9.59/18.5	2.57/12.4	3 550/4 568	< 1 000/1 249
Byron Creek	E. Kootenay	Byron Creek	14 000/25 430	674/702.9	< 5.0/8.2	0.65/-	2 380/2 708	4 860/1 354
Kaiser Resources	E. Kootenay	Kaiser (Seam No. 7)	17 000/14 050	386/324.8	6.67/11.3	1.77/-	3 610/3 769	100/157.9
Kaiser Resources	E. Kootenay	Elk View	18 900/24 520	200/104.4	4.06/11.9	1.49/-	540/803.6	585/373.6
Kaiser Resources	E. Kootenay	Elk View*	15 900/13 380	200/77.1	2.56/8.0	0.96/-	1 490/1 499	515/247.7
Fording Coal	E. Kootenay	Fording	15 400/14 320	200/71.8	13.0/11.0	2.18/-	2 060/2 087	< 1 000/262.1

* Clean coal samples

TABLE 6 COMPARISON OF TRACE ELEMENT CONCENTRATIONS (IN PPM) AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS AND PLASMA EMISSION SPECTROMETRY (cont'd.)

Company	Field	Mine	Manganese NAA/PES	Potassium NAA/PES	Sodium NAA/PES	Strontium NAA/PES	Thorium NAA/PES	Titanium NAA/PES	Vanadium NAA/PES
NOVA SCOTIA									
River Herbert	Joggins	River Herbert	219/208.4	10 900/9 163	1 390/-	< 500/73.7	2.95/4.7	1 160/1 005	49.1/55.4
Thorburn	Pictou	Acadia	132/102.6	7 350/7 156	517/1 806	<100/121.6	3.62/1.9	2 920/901.8	58.0/59.7
Devco	Sydney	Lingan	96.9/102.5	360/290.3	143/-	< 70/10.4	0.30/2.7	400/127.0	3.88/5.3
Devco	Sydney	No. 26	58.5/33.6	< 100/72.3	45.0/361.4	< 70/4.8	0.20/-	340/77.3	5.34/3.3
Devco	Sydney	Prince	51.3/49.2	3 150/3 318	355/-	174/130.8	2.03/6.1	644/677.7	9.13/28.3
NEW BRUNSWICK									
N.B. Electric Power	Minto	Minto	378/335.2	< 100/1 694	389/-	< 100/43.8	1.16/3.6	1 670/519.2	26.98/21.0
N.B. Coal	Minto	Minto	526/454.2	< 200/1 068	1 92/-	< 100/45.9	1.10/2.9	1 270/510.0	31.6/25.8
SASKATCHEWAN									
Manitoba Power	Estevan	Estevan	47.5/33.9	627/805.7	4 090/-	414/380.9	2.14/6.4	508/564.9	7.56/9.0
M&S Coal	Estevan	Bienfait	24.3/18.8	< 200/691.6	6 820/-	170/401.7	3.23/6.6	1 730/891.5	5.01/9.0
M&S Coal	Estevan	Boundary Dam	26.3/19.8	< 200/797.8	6 740/7 209	162/456.6	2.70/-	1 650/747.8	7.93/10.9
Sask. Power Corp.	Estevan	Boundary Dam	34.9/27.5	1 770/1 459	7 560/8 279	240/426.8	1.99/1.0	421/592.4	22.4/31.7
Sask. Power Corp.	Estevan	Queen Eliz.	106/110.1	822/813.8	1 820/-	<400/201.1	1.85/1.9	162/282.4	4.65/5.1
Manalta	Estevan	Klimax	48.2/38.9	< 700/75.0	4 660/5 435	681/551.9	3.68/2.8	626/874.3	4.74/7.5
Poplar River	Core Sample	Exploratory	125/112.0	3 280/2 988	1 090/2 203	<600/259.5	3.36/2.9	681/688.6	17.2/20.1
Poplar River	Core Sample	Exploratory	127/98.6	2 370/1 972	994/1 855	<600/217.7	3.92/2.9	678/528.1	17.5/1.52

TABLE 6 COMPARISON OF TRACE ELEMENT CONCENTRATIONS (IN PPM) AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS AND PLASMA EMISSION SPECTROMETRY (cont'd.)

Company	Field	Mine	Manganese NAA/PES	Potassium NAA/PES	Sodium NAA/PES	Strontium NAA/PES	Thorium NAA/PES	Titanium NAA/PES	Vanadium NAA/PES
ALBERTA									
Manalta	Sheerness	Roselyn	113/154.2	< 100/1 440	1 150/1 776	< 100/211.3	1.82/1.9	500/388.9	4.72/6.3
McIntyre	Grande Cache	McIntyre	10.0/5.0	786/241.9	570/837.2	88.9/142.3	1.51/-	1 550/654.9	26.3/26.9
McIntyre	Grande Cache	McIntyre	11.5/3.8	554/318.4	9 150/670.2	< 500/163.4	1.55/-	654/628.4	26.9/31.1
Luscar Coal	Castor	Diplomat	26.9/25.1	585/743.0	1 370/-	217/254.3	1.48/6.7	220/194.3	2.83/3.0
Manalta	Castor	Vesta	36.2/46.8	1 040/846.2	3 150/3 891	230/374.5	2.11/-	161/216.9	0.94/2.8
Century Coals	Drumheller	Altlas	76.5/102.7	1 030/1 007	3 830/-	374/355.6	2.88/-	213/288.4	2.11/4.3
Manalta	Pembina	Highvale	56.8/97.3	352/362.1	2 470/3 709	< 500/145.7	2.96/3.5	451/538.7	4.09/6.5
Manalta	Pembina	Whitewood	144/154.2	719/660.9	228/969.2	< 400/62.0	2.72/3.5	556/500.5	9.47/9.1
Sundance Mines	Edmonton	Sundance	82.5/86.8	360/266.2	3 180/3 212	< 500/144.1	2.55/1.8	403/509.4	9.29/10.5
Imperial Oil	Edmonton	Judy Creek	141/151.6	1 460/775.8	1 910/-	< 600/133.5	6.17/9.0	942/1001	10.62/15.2
Coleman Collieries	Crowsnest	Vicary Creek	21.7/12.1	< 200/734.7	300/-	170/200.0	2.93/6.5	2 520/1 116	33.8/34.9
Coleman Collieries	Crowsnest	Tent Mountain	20.1/10.4	584/307.9	241/373.2	< 500/223.9	4.82/-	989/1 316	62.9/44.4
Cardinal River	Mountain Park	Cardinal River	15.1/6.4	489/204.8	1 000/-	< 400/128.5	2.22/0.9	420/530.7	11.8/14.9
BRITISH COLUMBIA									
B.C. Hydro	Ashcroft	Hat Creek	172/177.2	3 060/3 412	680/2 654	< 200/124.1	2.54/3.8	5.5/3 080	93.5/125.1
B.C. Hydro	Ashcroft	Hat Creek*	41.2/29.4	< 100/1 538	787/1 945	< 90/67.6	1.45/-	3 010/1 768	108/128.2
Tulameen	Tulameen	Tulameen	53.5/54.3	1 750/2 774	165/0	< 90/23.1	2.19/2.9	1 600/838.8	34.3/38.9
B.P. Canada	Chetwynd	Sukunka	18.4/7.7	3 370/3 250	786/1 409	< 600/119.3	1.79/-	688/741.1	68.8/66.6
Denison Coal	E. Kootenay	Denison	10.7/7.5	< 200/419.6	448/-	65.5/100.1	1.56/1.9	983/477.8	23.4/24.6
Byron Creek	E. Kootenay	Byron Creek	32.7/15.9	612/359.3	810/1 290	< 600/234.0	1.26/-	1 110/1 621	18.6/29.2
Kaiser Resources	E. Kootenay	Kaiser (Seam No. 7)	19.5/9.6	< 100/428.9	84.7/365.0	< 70/130.5	1.62/-	2 520/756.4	46.4/40.0
Kaiser Resources	E. Kootenay	Elk View	13.4/4.5	1 160/785.4	42.8/287.4	< 500/26.1	1.35/-	945/1 226	23.8/27.1
Kaiser Resources	E. Kootenay	Elk View*	20.8/-	460/161.3	44.8/-	< 500/22.7	1.45/-	733/780	19.4/22.8
Fording Coal	E. Kootenay	Fording	23.5/16.0	1 165/589.7	57.8/-	< 500/36.2	1.97/-	1 040/864.8	39.4/38.8

* Clean coal samples

TABLE 7 COMPARISON OF TRACE ELEMENT CONCENTRATIONS (IN PPM) AS DETERMINED BY PLASMA EMISSION SPECTROMETRY AND ATOMIC ABSORPTION SPECTROMETRY

			Copper	Iron	Lead	Manganese	Zinc
Company	Field	Mine	PES/AAS	PES/AAS	PES/AAS	PES/AAS	PES/AAS
NOVA SCOTIA							
Devco	Sydney	No. 26	3.6/6.7	2 929/3 250	1.8/0.9	33.6/61.8	5.4/10.5
SASKATCHEWAN							
Poplar River	Core Sample	Exploratory	14.5/18.6	4 675/5 749	17.6/20.8	98.6/107.4	22.5/19.5
ALBERTA							
McIntyre	Grande Cache	McIntyre	9.8/10.9	432.6/1 885	5.0/9.2	3.8/5.9	50.3/44.4
Coleman Collieries	Crowsnest	Tent Mountain	16.2/17.7	1 913/1 987	11.2/13.9	10.4/12.1	53.2/28.9
BRITISH COLUMBIA							
B.C. Hydro	Ashcroft	Hat Creek	61.4/68.2	20 560/21 133	3.8/19.9	177.2/183.9	58.8/56.9
B.C. Hydro	Ashcroft	Hat Creek*	58.7/62.8	9 989/10 784	7.1/12.4	29.4/31.8	35.4/56.9
B.P. Canada	Chetwynd	Sukunka	8.8/9.4	3 926/4 245	5.6/8.4	7.7/8.5	29.1/28.2
Byron Creek	E. Kootenay	Byron Creek	12.5/13.8	2 708/2 929	5.5/11.0	15.9/19.34	10.1/10.1
Kaiser Resources	E. Kootenay	Kaiser (Seam No. 7)	15.1/15.5	3 769/3 832	2.7/6.3	9.6/11.0	18.2/15.6
Kaiser Resources	E. Kootenay	Elk View	9.0/8.62	803.6/729	5.7/5.7	4.5/4.8	88.1/14.4

* Clean coal samples

APPENDICES

APPENDIX 1

SAMPLE PREPARATION AND DISSOLUTION TECHNIQUES

Homogeneous coal samples for analysis by AAS and PES were prepared by first thoroughly mixing portions of the top, middle, and bottom of the bulk coal samples. The prepared coal samples were dried overnight in a desiccator (the weight loss on drying was negligible; 0.06 to 1.1%) and then weighed in porcelain dishes and placed in a cold muffle furnace. The temperature of the furnace was raised, in 50 C degree steps, to 750 degrees C over two hours and maintained at this temperature for 24 hours.

Siliceous material in the ash produced by this high temperature ashing procedure was removed by the addition of hydrofluoric acid (HF) followed by slow evaporation to dryness. The residues from the HF treatment were then dissolved using one of the methods listed below. The coals corresponding to the identification numbers are given in Table 8.

Group 1

The residue was dissolved in a mixture of 5 ml NHO_3 and 3 ml HCl and made up to 100 ml with water.

Nova Scotia	Saskatchewan	Alberta	British Columbia
2	15	18, 27	34, 35, 36, 37

Group 2

The residue was dissolved in 5 ml HNO_3 and made up to 100 ml with water.

Nova Scotia	Saskatchewan	Alberta	British Columbia
4	10, 11, 13, 14	16, 17, 20, 22, 23, 26	38

Group 3A

The residue was treated with a mixture of 5 ml HNO_3 and 3 ml HCl. Undissolved material was filtered and fused with a mixture of lithium and sodium tetraborates. The fused material was dissolved in the original filtrate and made up to 100 ml with water.

Nova Scotia	Alberta	British Columbia
1	25	31, 33

Group 3B

The same procedure was followed as for Group 3A, except that nitric acid rather than aqua regia was used in the first dissolution step.

Nova Scotia	New Brunswick
3, 5	6, 7

Group 4

The residue was treated with 5 ml HNO_3. A very small amount of undissolved material remained; it was filtered, dissolved in 1 ml of 40% NaOH solution, acidified and then added to the original filtrate which was made up to 100 ml with water.

Saskatchewan	Alberta
8, 9, 12	19, 21, 26, 28

TABLE 8 COAL IDENTIFICATION NUMBERS FOR SAMPLE DISSOLUTION TECHNIQUES

Number	Company	Field	Mine
	NOVA SCOTIA		
1	River Herbert	Joggins	River Herbert
2	Thorburn	Pictou	Acadia
3	Devco	Sydney	Lingan
4	Devco	Sydney	No. 26
5	Devco	Sydney	Prince
	NEW BRUNSWICK		
6	N.B. Electric Power	Minto	Minto
7	N.B. Coal	Minto	Minto
	SASKATCHEWAN		
8	Manitoba Power	Estevan	Estevan
9	M&S Coal	Estevan	Bienfait
10	M&S Coal	Estevan	Boundary Dam
11	Sask. Power Corp.	Estevan	Boundary Dam
12	Sask. Power Corp.	Estevan	Queen Eliz.
13	Manalta	Estevan	Klimax
14	Poplar River	Core Sample	Exploratory
15	Poplar River	Core Sample	Exploratory
	ALBERTA		
16	Manalta	Sheerness	Roselyn
17	McIntyre	Grande Cache	McIntyre
18	McIntyre	Grande Cache	McIntyre
19	Luscar Coal	Castor	Diplomat
20	Manalta	Castor	Vesta
21	Century Coals	Drumheller	Atlas
22	Manalta	Pembina	Highvale
23	Manalta	Pembina	Whitewood
24	Sundance Mines	Edmonton	Sundance
25	Imperial Oil	Edmonton	Judy Creek
26	Coleman Collieries	Crowsnest	Vicary Creek
27	Coleman Collieries	Crowsnest	Tent Mountain
28	Cardinal River	Mountain Park	Cardinal River
	BRITISH COLUMBIA		
29	B.C. Hydro	Ashcroft	Hat Creek
30	B.C. Hydro	Ashcroft	Hat Creek*
31	B.P. Canada	Tulameen	Tulameen
32	B.P. Canada	Chetwynd	Sukunka
33	Denison Coal	E. Kootenay	Denison
34	Byron Creek Co.	E. Kootenay	Byron Creek
35	Kaiser Resources	E. Kootenay	Kaiser (Seam No. 7)
36	Kaiser Resources	E. Kootenay	Elk View
37	Kaiser Resources	E. Kootenay	Elk View*
38	Fording Coal	E. Kootenay	Fording

* Clean coal samples

APPENDIX 2

DETERMINATION OF TRACE ELEMENTS IN NBS STANDARD REFERENCE COALS

To provide quality control assurance for the analytical data obtained in this study, the trace element concentrations in two National Bureau of Standards reference coals (NBS 1632 and 1632a) were determined by the same measurement techniques (NAA, PES and AAS) employed for the 38 coal samples. The results of these determinations are given in Tables 9-12, together with the certified and informational trace element concentrations reported by NBS.

It will be seen from Tables 9 and 10 that the NAA results are generally in good agreement with the NBS values. An exception is the NAA result for manganese (Table 10), which is significantly higher than the NBS certified value. However, this discrepancy is not unexpected because the 847-keV gamma line from Mn-56 (the isotope measured in the instrumental NAA determination of manganese) cannot be fully resolved by the Ge(Li) gamma-ray detector from the 844-keV gamma line from Mg-27 (produced by the Al-27 (n,p) Mg-27 reaction). This spectral interference gives a positive bias to the manganese concentration measurement.

The concentrations of trace elements, as determined by atomic absorption spectrometry, in the standard reference coal NBS 1632 (Table 11) are in excellent agreement with the NBS certified values, with only the results for chromium and nickel falling somewhat outside the given confidence limits. The plasma emission spectrometry results (Table 12) were, in general, less accurate than those obtained by AAS and NAA, and PES would therefore probably not be the method of choice for those elements that can be determined by the other methods.

From the results given in Tables 9-12, it would appear that for trace element determinations in coal where speed, economy, and reasonable accuracy are required, that NAA is the most advantageous analytical method to use, bearing in mind, of course, that not all elements can be determined by this method.

TABLE 9 RESULTS OF NEUTRON ACTIVATION ANALYSIS DETERMINATION OF THE CONCENTRATION OF TRACE ELEMENTS IN NATIONAL BUREAU OF STANDARDS REFERENCE COAL, NBS 1632

Element	NBS Value[1] Concentration (μg/g)	NAA Result[2] Concentration (μg/g)
Arsenic	5.9 ± 0.6	5.34 ± 0.6
Chromium	20.2 ± 0.5	21.2 ± 3.4
Cobalt	(6)	5.51 ± 0.9
Iron	8 700 ± 300	8 590 ± 950
Manganese	40 ± 3	53.6 ± 11
Selenium	2.9 ± 0.3	<6
Tellurium	(<0.1)	<2.0
Thorium	(3.0)	2.61 ± 0.3
Uranium	1.4 ± 0.1	1.34 ± 0.1
Vanadium	35 ± 3	33.1 ± 4

1 Concentrations in parentheses are reported by NBS for information purposes only and are not certified values. Other concentrations are certified values at the 95% or greater confidence limit.

2 Errors in NAA determinations are the sum of a 5% sample handling error and a one-standard-deviation counting-statistics error.

TABLE 10 RESULTS OF NEUTRON ACTIVATION ANALYSIS DETERMINATION OF THE CONCENTRATION OF TRACE ELEMENTS IN NATIONAL BUREAU OF STANDARDS REFERENCE COAL, NBS 1632a

Element	NBS Value[1] Concentration (μg/g)	NAA Result[2] Concentration (μg/g)
Aluminum	(30 700)	33 800 ± 2 000
Antimony	(0.58)	<0.7
Arsenic	9.3 ± 1	7.15 ± 0.7
Cerium	(30)	21.7 ± 3
Chromium	34.4 ± 1.5	31.3 ± 4
Cobalt	(6.8)	5.83 ± 0.9
Europium	(0.54)	0.71 ± 0.2
Hafnium	(1.6)	1.44 ± 0.3
Iron	11 100 ± 200	11 200 ± 1 000
Manganese	28 ± 2	46.9 ± 12
Scandium	(6.3)	5.82 ± 0.4
Selenium	2.6 ± 0.7	<6.0
Thorium	4.5 ± 0.1	3.8 ± 0.5
Titanium	(1 750)	1 770 ± 270
Uranium	1.28 ± 0.02	0.87 ± 0.09
Vanadium	44 ± 3	42.3 ± 5

1 Concentrations in parentheses are reported by NBS for information purposes only and are not certified values. Other concentrations are certified values at the 95% or greater confidence limit.

2 Errors in NAA determinations are the sum of a 5% sample handling error and a one-standard-deviation counting-statistics error.

TABLE 11 RESULTS OF ATOMIC ABSORPTION SPECTROMETRY DETERMINATION OF THE CONCENTRATION OF TRACE ELEMENTS IN NATIONAL BUREAU OF STANDARDS REFERENCE COAL, NBS 1632

Element	NBS Value[1] Concentration (μg/g)	AAS Result Concentration (μg/g)
Arsenic	5.9 ± 0.6	5.7
Cadmium	0.19 ± 0.03	0.19
Chromium	20.2 ± 0.5	19
Copper	18 ± 2	18.3
Iron	8 700 ± 300	8 650
Lead	30 ± 9	33.2
Manganese	40 ± 3	40.8
Nickel	15 ± 1	19
Vanadium	35 ± 3	32
Zinc	37 ± 4	36.8

1 Concentrations in parentheses are reported by NBS for information purposes only and are not certified values. Other concentrations are certified values at the 95% or greater confidence limit.

TABLE 12 RESULTS OF PLASMA EMISSION SPECTROMETRY DETERMINATION OF THE CONCENTRATION OF TRACE ELEMENTS IN NATIONAL BUREAU OF STANDARDS REFERENCE COAL, NBS 1632

Element	NBS Value[1] Concentration (μg/g)	PES Result Concentration (μg/g)
Chromium	20.2 ± 0.5	17
Copper	18 ± 2	13.8
Iron	8 700 ± 300	8 210
Lead	30 ± 9	23
Manganese	40 ± 3	39.7
Vanadium	35 ± 3	23.7

1 Concentrations in parentheses are reported by NBS for information purposes only and are not certified values. Other concentrations are certified values at the 95% or greater confidence limit.

POOR

QUALITY

ORIGINAL